ND 803 Spring Wheat Germplasm Combining Resistance to Scab and Leaf Diseases with Good Agronomic and Quality Traits

Mohamed Mergoum,* Richard C. Frohberg, Robert W. Stack, Pawan K. Singh, Tika B. Adhikari, Jack B. Rasmussen, Mohammed S. Alamri, and Timothy L. Friesen

ABSTRACT

The development of adapted wheat germplasm is essential so that breeding programs can develop superior cultivars, which was the objective of this research. ND 803 is hard red spring wheat (HRSW; *Triticum aestivum* L.) line that was developed at North Dakota State University (NDSU) and released by the North Dakota Agricultural Experiment Station (NDAES). ND 803 (Reg. No. GP-947, PI 665931 was derived from the ND2831/FO.2808 cross made at NDSU in fall 1997. ND2831 ('Sumai3' [PI 481542]/'Stoa' [PI 520297]) is a hard red spring experimental line with good resistance to Fusarium head blight (FHB), or scab [caused by *Fusarium graminearum* Schwabe; telomorph *Gibberella zeae* (Schwein.) Petch] originating from 'Sumai3', which is known to possess the *Fhb1* quantitative trait locus. Sumai3 is a spring wheat from China that is arguably the most widely used source of resistance to FHB in the world. Stoa is an HRSW cultivar released by NDSU in 1984. FO.2808 ('Grandin' [PI 531005]/3/IAS20*4/H567.71//'Amidon' [PI 527682]/ND674) is an HRSW line developed by the NDSU HRSW breeding program. Amidon and Grandin are HRSW cultivars released by NDAES in 1988 and 1989, respectively. IAS20*4/H567.71 is a public breeding line received from CIMMYT. ND 803 was produced from a bulk of one purified $F_{5:6}$ plot selected in 2000 at Prosper, ND. ND 803 was released because it combines good agronomic and end-use quality with resistance to both FHB and leaf diseases.

ND 803 (Reg. No. GP-947, PI 665931) hard red spring wheat (HRSW) (*Triticum aestivum* L.) was developed at North Dakota State University (NDSU), and released by the North Dakota Agricultural Experiment Station (NDAES). In addition to researchers at NDSU, USDA-ARS researchers at Fargo, ND contributed by testing ND 803 for leaf rust (caused by *Puccinia triticina* Eriks.) and stem rust (caused by *Puccinia graminis* Per.:Pers. f. sp. *tritici* Eriks. & E. Henn) resistance. ND 803 was released because it combines good agronomic traits, good end-use quality and resistance to both Fusarium head blight [FHB; caused by *Fusarium graminearum* Schwabe; telomorph *Gibberella zeae* (Schwein.) Petch] and major leaf diseases. It was derived from the ND2831/FO.2808 cross made at NDSU in fall 1997. ND2831 ('Sumai3' [PI 481542]/'Stoa' [PI 520297]) is a hard red spring experimental line with good resistance to FHB originating from 'Sumai3', which is known to possess the *Fhb1* quantitative trait locus. Sumai3, is a spring wheat from China and is arguably, the most widely used source of resistance to FHB in the world. FO.2808ND2814 ('Grandin' [PI 531005]/3/IAS20*4/H567.71//'Amidon'[PI 527682]/ND674) is an HRSW line developed by the NDSU HRSW breeding program. Amidon and Grandin are HRSW cultivars released by NDAES in 1988 and 1989, respectively. IAS20*4/H567.71 is a public breeding line received from CIMMYT. ND 803 was produced from a bulk of one purified $F_{5:6}$ plot selected in 2001 at Prosper, ND. ND 803 combines good agronomic, end-use quality with resistance to both FHB and leaf diseases.

M. Mergoum and R.C. Frohberg (retired), Dep. of Plant Sciences, North Dakota State Univ., P.O. Box 5051, Fargo, ND 58105; R.W. Stack (retired), T.B. Adhikari, and J.B. Rasmussen, Dep. of Plant Pathology, North Dakota State Univ., P.O. Box 5051, Fargo, ND 58105; P.K. Singh, CIMMYT, Km. 45, Carretera México-Veracruz, El Batán, Texcoco CP 56130, Edo. de México, Mexico; M.S. Alamri, Nutrition and Food Sciences Dep., College of Food and Agricultural Sciences; King Saud University, P.O. Box 2460, Riyadh 11451, Saudi Arabia; T.L. Friesen, USDA-ARS, Fargo, ND. *Corresponding author (mohamed.mergoum@ndsu.nodak.edu).

Abbreviations: AYT, advanced yield trials; FHB, Fusarium head blight; HRSW, hard red spring wheat; HRSW-VT, HRSW variety trial; NDAES, North Dakota Agricultural Experiment Station; NDSU, North Dakota State University; PYT, preliminary yield trials; RCBD, randomized complete block design; URN, Uniform Regional Nursery; SNB, Stagonospora nodorum blotch; STB, Septoria tritici blotch.

Published in the Journal of Plant Registrations.
doi: 10.3198/jpr2012.05.0270crg
Received 1 May 2012. Registration by CSSA.

5585 Guilford Rd., Madison, WI 53711 USA

Methods

Early-Generation Development

ND 803 was developed using a modified bulk-breeding procedure. The F_1 seeds from the cross leading to ND 803 were grown in the greenhouse at Fargo, ND in spring 1997, and the F_2 population was also grown in the greenhouse at Fargo, ND in the fall of 1997 and also was screened for stem rust. From the F_2 population, 100 spikes were harvested, threshed individually, and grown as F_3 rows in the stem rust nursery at Prosper in summer of 1998. Subsequently, selected F_3 rows were harvested and threshed in bulk and sown in F_4 row plots at an off-season winter nursery near Christchurch, New Zealand during the spring of 1999. Plots harvested from the New Zealand nursery were planted in the F_5 preliminary yield trials (PYT) at Prosper and Casselton, ND in summer 1999. Ten spikes were selected, harvested, threshed individually, and grown as $F_{5:6}$ rows in the stem rust nursery at Prosper in the summer of 2000. Selected rows were harvested in bulk and reentered again as $F_{5:7}$ in the PYT at Prosper and Casselton, ND in summer 2001. One row (01-15-1066) was selected, harvested in bulk, and entered in the advanced yield trials (AYT) in summer 2002. Seed from this row was also used as the seed source for hill plots in the FHB nursery at Prosper, ND in the summers of 2002 to 2005. The FHB nursery was inoculated with the FHB pathogen using the spray inoculation method (Rudd et al., 2001) and overhead mist irrigation to enhance disease development. Evaluation for FHB reaction was done on 10 random spikes from each hill and were scored for FHB disease severity (Stack et al., 1997). Selections in the F_2 and F_3 generations were based on reactions to stem and leaf rust and on agronomic merits, including plant vigor, height, and earliness. Selection in the F_4 at the New Zealand off-season winter nursery was mainly done on visual uniformity, lack of grain shattering, plant height, and lodging resistance.

Line Selection and Evaluation

ND 803 was evaluated for agronomic and quality traits in the PYT in 1999 and 2001 and in the AYT in 2002. Subsequently, ND 803 was tested in the North Dakota HRSW Variety Trials (HRSW-VTs) from 2003 to 2006. ND 803 was also tested in the spring wheat Uniform Regional Nursery (URN) in 2005 and 2006. All yield trials were arranged in a randomized complete block design (RCBD) with two replicates for PYT and four replicates for AYT. The experimental unit consisted of seven rows that were 3 m long, and 30 cm apart. While PYT were grown only in Casselton and Prosper, ND, the AYTs were grown at four locations (Casselton, Minot, Carrington, and Prosper). The HRSW-VT is a statewide trial conducted at seven locations across ND in an RCBD with four replicates. The plot size consisted of eight rows that were 10 m long, and 30 cm apart. The URN was conducted during 2005 and 2006 in 37 location-years across the states of North Dakota, Minnesota, South Dakota, Nebraska, Montana, Wyoming, and Washington, and in Manitoba, Canada. These trials were laid out in a RCBD with three replicates. Depending on location, the experimental unit consisted of six to eight rows that were 3 m long, and 30 cm apart.

ND 803 was tested for its reaction to different races of tan spot [caused by *Pyrenophora tritici-repentis* (Died.) Drechs], Stagonospora nodorum blotch [SNB; caused by *Stagonospora nodorum* (Berk.) Castellani & E.G. Germano] and Septoria tritici blotch [STB; caused by *Mycosphaerella graminicola* (Fückl) J. Schröt. in Cohn; anamorph, *Septoria tritici* Roberge in Desmaz.], leaf and stem rusts, and FHB in greenhouse and field tests during 2000 to 2006. The tan spot disease is a major component of the leaf spotting complex of wheat in North America. This complex includes tan spot, STB, and SNB. Thus, managing leaf spot diseases is difficult; however, resistant cultivars are the most effective and economical means of controlling leaf spot.

In wheat, tan spot can cause two phenotypically distinct and independent symptoms: tan necrosis and extensive chlorosis (Lamari and Bernier, 1989). Presently, eight races of tan spot have been identified (Lamari et al., 2003). From 2003 to 2006, ND 803 was tested for resistance to four races of tan spot in six greenhouse trials. The races tested included all the virulent races observed in North America (i.e., race 1, the most prevalent tan spot race in North Dakota and the races 2, 3, and 5). These trials were arranged as an RCBD with three replicates and three plants per replicate as the experimental unit. The plants were evaluated according to the lesion-type scale (1–5) developed by Lamari and Bernier (1989), in which 1 indicates resistance, with lesions of small, dark brown to black spots without any surrounding chlorosis or tan necrosis, and 5 indicates susceptibility with lesions of dark brown or black centers that may or may not be distinguishable and most lesions consist of coalescing chlorotic and tan necrotic zones. Similarly, for SNB and STB, plants were rated on a scale of 1 to 5, in which a rating of 2 or less indicates resistance (R) and greater than 2 indicates susceptibility (S).

ND 803 was also screened extensively for resistance to FHB from 2002 to 2006 in 12 FHB nurseries under both field (eight location-years) and greenhouse (four experiments) conditions. The field FHB nursery was located at Prosper, ND and was laid out in an RCBD with four replicates. Each entry was assigned to a hill plot consisting of 8 to 10 plants. Similarly, the greenhouse experiments were arranged in an RCBD with three replicates. The entries were assigned to a 0.25-m row plot.

Screening for stem and leaf rust is crucial for developing adapted germplasm for the northern plains of the USA. Therefore, collection of reaction-type observations for ND 803 to the prevalent races of leaf and stem rusts started early in the segregating generations. Most important, rust screening was continued in later stages when ND 803 was also entered in yield trials. This screening was done in six field tests (RCBD, four replicates, and 1-m row plot per replicate) and eight greenhouse tests (RCBD, three replicates, and four plants per replicate) from 2003 to 2006. In the greenhouse experiments, all germplasm, including ND 803, was specifically screened for reactions to the predominant leaf rust pathotypes MCDL and THBJ. Additional testing for stem rust included naturally inoculated field nurseries at

two North Dakota locations (Langdon and Carrington) and an artificially inoculated field nursery at Fargo, ND with races TPMK, TMLK, RTQQ, QFCQ, and QTHJ. ND803 was evaluated in these three field nurseries from 2003 to 2006. ND803 was also evaluated in the greenhouse from 2003 to 2006 using individual inoculations of the same races used in the Fargo field inoculation.

Seed Purification

ND 803 was first produced from a bulk of purified $F_{5:6}$ headrows selected in 2000 at Prosper, ND. Based on the good performance of ND 803, it was further purified for the purpose of cultivar release. This purification consisted of selecting 100 spikes from the quality drill strips (F_9) grown at Casselton, ND in 2003. These spikes were threshed individually and seeded as headrows at Casselton in 2004. Nonuniform rows were discarded and the remaining rows were bulked and planted in 2006 at Prosper, ND.

Statistical Analysis

Data were analyzed with SAS-JMP version 6.0.3 (SAS Institute Inc.). Grain yield and other agronomic data, such as grain volume weight from the AYT and HRSW-VT, were subjected to analysis of variance across locations within years, and a combined analysis across location-years was performed whenever error variances were homogeneous. The analysis of AYT, HRSW-VT, and URN included only entries common to the trials across years. A mixed model with environments and genotypes as fixed effects and replications within environments as random effects was used for within-year analyses. Similarly, across-year analyses were also done according to a mixed model with genotypes as fixed effects and location-year and replications as random effects. Tukey's HSD test ($\alpha = 0.05$) was used to compare the least squares means for the genotype effects.

Characteristics

Agronomic and Botanical Description

ND 803 is an awned, early maturing, and semidwarf hard spring wheat. It has a lax head type and at 86 cm is significantly taller than 'Alsen' (PI 615543; Frohberg et al., 2006) and 'Reeder' (PI 613586) (80 cm) but shorter than 'Dapps' (PI 633862, Mergoum et al., 2005a) (93 cm). The plant height of ND 803 was, however, similar to that of 'Steele-ND' (PI 634981; Mergoum et al., 2005b), 'Howard' (PI 642367; Mergoum et al., 2006b), and 'Parshall' (PI 613587) (Table 1). In the URN trials, the height of ND 803 was 85 cm, which was comparable to that of 'Verde' (PI 592561; Busch et al., 1996) (79 cm) and '2375' (82 cm) but significantly shorter than that of 'Keene' (PI 598224 PVP) (96 cm) and 'Chris' (CItr 13751; Heiner and Johnston, 1967) (100 cm) (Table 2). ND 803 heads, in general, the same time as Dapps, Parshall, and Alsen, but significantly earlier than Reeder, Steele-ND, Howard, and 'Glenn' (PI 639273; Mergoum et al., 2006a) (Table 1). ND 803 heads on the same day as Verde and Keene and 1 d earlier, but not significantly, than Chris (Table 2). Straw strength, which is directly related to plant lodging, was measured on a scale of 0 to 9, where 0 = completely erect, and 9 = totally flat at harvest. ND 803 was medium resistant to lodging (lodging score = 2.0), similar to Steele-ND, a higher score than those for all other checks including Howard, Glenn, and Dapps, which had lodging scores of 0.5, and Reeder, which had a score of 0.2 (Table 1). In the URN, the lodging score of ND 803 was 1, which was similar to that of Verde but significantly better than that of than Keene and Chris (Table 2).

ND 803 has erect flag leaves that are slightly twisted and shows a waxy canopy at the boot stage. The heads of ND 803 are white, awned, middense, and inclined. The glumes of ND 803 are white, medium long, and wide, with elevated medium-width shoulders and acuminate beaks. The kernels of ND 803 are ovate, red, and hard textured, with a long noncollared brush, a rounded cheek, a medium-wide and medium-deep crease, and a mid- to large-size germ.

Disease Reactions

Disease pressure from FHB was usually high in the scab nurseries. The average disease severity (Stack and Frohberg, 2000) recorded for ND 803 from the field scab nursery (32%) was significantly lower ($P < 0.05$) than for the susceptible check Reeder (55%) and the very susceptible check 2398

Table 1. Summary of agronomic data for ND 803 and check cultivars tested in ND Hard Red Spring Wheat Variety Trials, 2003 to 2006.

Cultivar	Grain yield	Grain protein	1000-kernel weight	Grain volume weight	Heading date	Height	Straw strength
	kg ha^{-1}	g kg^{-1}	g	kg m^{-3}	d after 1 June	cm	score†
ND 803	4251cb‡	151a	30.1d	778b	25a	86bc	2.0c
Howard	3943b	153ab	29.0cd	778b	28bc‡	85b	0.5a
Glenn	3743a	157b	30.2d	797c	28bc	83ab	0.5a
Steele-ND	4052b	153ab	28.4bc	773b	29c	85b	2.0c
Dapps	3646a	165c	29.5c	756a	26a	93c	0.5a
Alsen	3763ab	157b	26.9ab	777b	27ab	80a	0.3a
Parshall	3607a	156b	26.5a	770b	27ab	86bc	0.2a
Reeder	3625a	155ab	26.7a	753a	29c	80a	1.0b
No. of environments	27	26	26	26	26	26	7

†0 = completely erect; 9 = completely flat at harvest.

‡Values within a column followed by the same letter are not significantly different at the $\alpha = 0.05$ probability level according to Tukey's HSD test.

Table 2. Summary of agronomic data for ND 803 and check cultivars tested in the Hard Red Spring Wheat Uniform Regional Nursery, 2005 and 2006.

Cultivar	Grain yield	Grain volume weight	Grain protein	Heading date	Height	Straw strength
	kg ha^{-1}	kg m^{-3}	g kg^{-1}	d after 1 June	cm	score†
ND 803	3742c‡	754c	144a	25ab	85a	1.0a
Verde	3743c	753bc	144a	25ab	79a	1.0a
2375	3717bc	767c	141a	24a	82a	0.9a
Keene	3213b	758c	144a	25ab	96b	1.6b
Chris	2738a	742ab	151b	26bc	100bc	2.9c
Marquis	2566a	737a	143a	27c	103c	2.4c
No. of environments	37	37	37	35	35	15

†0 = completely erect; 9 = completely flat at harvest.

‡Values within a column followed by the same letter are not significantly different at the $\alpha = 0.05$ probability level according to Tukey's HSD test.

(72%) (Table 3). In the same trials, the average FHB severities recorded on Alsen, Glenn, Parshall, Steele-ND, Dapps, and ND 2710 (PI 633976, Frohberg et al., 2004) were 26, 22, 38, 31, 42, and 13%, respectively. Among the medium-resistant checks, Alsen, which was released in 2000, was the first NDSU HRSW cultivar with a significantly higher level of resistance to FHB, and it dominated wheat acreage in North Dakota from 2001 to 2006. Glenn was also an NDSU HRSW released in 2005 with FHB resistance and has been the leading cultivar grown in North Dakota since 2007. Similarly, Howard and Steele-ND are both NDSU HRSW releases with FHB resistance derived from *Triticum dicoccoides* (Mergoum et al., 2005b, 2006b). Under greenhouse conditions (data not shown), the average FHB severity of ND 803 was 35%, which was not significantly different from the scores of Alsen (29%) and Glenn (30%) and was significantly lower ($P < 0.05$) than the 89 and 73% registered for the susceptible checks 2398 and Reeder, respectively. Field testing and greenhouse testing from 2003 to 2006 showed that ND 803 possesses a high level of resistance to pathotype THBJ, the predominant race of leaf rust in the region (Table 3). However, the reaction of ND 803 to the new emerging leaf rust race that defeated the *Lr21* gene is not well determined. Preliminary observations show that ND 803 is medium susceptible to this new race.

Table 3. Disease reactions of ND 803 nd check cultivars tested in ND Hard Red Spring Wheat Variety Trials between 2003 and 2006.

	FHB†		Leaf rust		Stem rust		Septoria‡		Tan spot			
Cultivar	Severity	VSK	GH§	Field	GH¶	Field	SNB	STB	Race 1	Race 2	Race 3	Race 5
	%						1–5#		1–5††			
ND 803	32	3	R‡‡	R–MR‡‡	R‡‡	TR‡‡	1.5(R)	1.5(R)	1.7	2.40	1.5	3.6
Alsen	26	2	R	MR/MS	MR/R	5R	4.4(S)	3.0 (S)	3.7	3.9	1.9	3.9
Glenn	22	1.5	R	R	R	R	4.1(S)	2.2	—	3.1	1.6	3.8
Parshall	38	4	MR	MR/MS	R	R	3.4(S)	3.0(S)	—	2.1	2.8	4.0
Dapps	42	5	R	R	R	R	1.4(R)	2.0(R)	—	3.6	3.1	3.2
Traverse	—	—	R	MR/MS	R	R	4.3(S)	3.0(S)	—	1.6	1.6	1.8
Knudson	—	3	—	R	R	R	1.6(R)	2.2	—	2.5	1.5	3.9
Reeder	55	7	R	S	MR/R	5R	2.4	2.9	2.5	2.1	2.0	4.0
Steele-ND	31	4	R	R	R	R	3.5(S)	2.8	3.7	3.9	1.9	3.9
2398	72	13	R	R	R	R	—	—	—	—	—	—
2710	13	1	R	R	R	R	—	—	—	—	—	—
Baart	—	—	S	S	S	50S	—	—	—	—	—	—
Glenlea	—	—	—	—	—	—	3.6(S)	2.4	4.3	2.0	—	1.9
Salamouni	—	—	—	—	—	—	1.5(R)	1.7(R)	1.4	1.4	2.0	1.3
6B662	—	—	—	—	—	—	1.5(R)	1.9(R)	1.7	1.7	1.7	4.0
6B365	—	—	—	—	—	—	1.7(R)	2.0(R)	1.7	4.1	4.1	1.9
No. of environments	4	4	9	5	4	9	4	4	6	6	6	6

†FHB, Fusarium head blight;% severity scored on 10 spikes (Stack and Frohberg 2000);VSK, visual scabby kernels.

‡SNB, Stagonospora nodorum blotch; STB, Septoria tritici blotch.

§Greenhouse reactions for leaf rust races MCDL and THBJ.

¶Greenhouse reactions for *P. graminis* f. sp. *tritici* races TPMK, TMLK, RTQQ, QFCQ, and QTHJ.

#≤2 = resistant (R); > 2 = susceptible (S).

††1 = resistant; 5 = Susceptible (Lamari and Bernier, 1989).

‡‡R, resistant; MR, moderately resistant; MS, moderately susceptible; S, susceptible; TR, trace/resistant; 5R, resistant with 5% disease severity; 50MS, moderately susceptible with 50% disease severity.

Table 4. Quality parameters for ND 803 and check cultivars tested in ND Hard Red Spring Wheat Variety Trials, 2003 to 2006.

Cultivar	Falling number	Flour extraction	Mixing time	Mixing tolerance	Loaf volume	Water absorption
	s	g kg^{-1}	min		mL	%
ND 803	426b†	695abc	7.0a	11.8a	1013ab	66.0b
Howard	427b	697bc	8.2bc	12.2ab	1007ab	64.5ab
Glenn	401a	676ab	9.3c	20.6d	1102d	64.9b
Steele-ND	425b	701c	8.5bc	13.5abc	1011ab	65.1b
Alsen	412ab	686abc	9.0bc	16.2d	1057bd	64.8ab
Parshall	415ab	692abc	8.3bc	14.9cd	1081c	64.7ab
Reeder	431b	678ab	7.0a	12.0a	1002a	63.8a
No. of environments	21	21	21	21	21	21

†Values within a column followed by the same letter are not significantly different at the $\alpha = 0.05$ probability level according to Tukey's HSD test.

ND 803 was found to be highly resistant to stem rust races TPMK, TMLK, RTQQ, QFCQ, and QTHJ under field and greenhouse conditions (Table 3). On a scale of 1 to 5, where 1 was resistant and 5 susceptible, ND 803 had average scores of 1.7, 2.4, 1.5, and 3.6 for tan spot races 1, 2, 3, and 5, while Reeder scored 2.5, 2.1, 2.0, and 4.0 for the same races (Table 3). The reactions of the check 'Salamouni' (PI 182673) to the races 1, 2, and 5 were 1.4, 1.4, and 1.3, and those of 'Glenlea' (CItr 17272) were 4.3, 2.0, and 1.9. Salamouni is considered among the best sources of resistance to tan spot, whereas Glenlea is usually used as the susceptible check to races 1 and 2 (Table 3). ND 803 was resistant to both SNB and STB, with scores of 1.5 (on a scale of 1 to 5), whereas the principal cultivars grown in the region since 2002 (Alsen and Glenn) are susceptible to SNB and susceptible to moderately resistant to STB (Table 3).

Agronomic and Quality Performance

Data presented for agronomic traits are based on 27 location-years of testing in the HRSW-VT. The grain yield of ND 803 (4251 kg ha^{-1}) was not significantly ($P < 0.05$) higher than the commonly grown NDSU cultivars, including Alsen (3763 kg ha^{-1}), Steele-ND (4052 kg ha^{-1}, and Howard (3943 kg ha^{-1}) (Table 1). However, ND 803 had a significantly higher yield than Glenn (3743 kg ha^{-1}), Dapps (3646 kg ha^{-1}), Parshall (3607 kg ha^{-1}), and Reeder (3625 kg ha^{-1}). In the 37 location-years of testing in the URN trials conducted in 2005 and 2006, ND 803 yielded 3742 kg ha^{-1} compared with 3213, 3743, and 2738 kg ha^{-1} for Keene, Verde, and Chris, respectively (Table 2). ND 803 had an average 1000-kernel weight of 30.1 g compared with 29.0, 30.2, 28.4, 29.5, 26.9, 26.5, and 26.7 g for Howard, Glenn, Steele-ND, Dapps, Alsen, Parshall, and Reeder (Table 1). The mean grain volume weight of ND 803 (778 kg m^{-3}) across 26 location-years in HRSW-VT was similar to that of Howard (778 kg m^{-3}), Steele-ND (773 kg m^{-3}), Alsen (777 kg m^{-3}), and Parshall (770 kg m^{-3}); however, it was higher than that of Reeder (753 kg m^{-3}) and Dapps (756 kg m^{-3}), but significantly ($P < 0.05$) lower than that of Glenn (797 kg m^{-3}) (Table 1). In the URN, the mean grain volume weight of ND 803 was 754 kg m^{-3} compared with 753, 767, 758, 742, and 737 kg m^{-3} for Verde, 'Pioneer 2375', Keene, Chris, and 'Marquis' (CItr 3641; Clark, 1926), respectively (Table 2). The grain protein content of ND 803 (151 g kg^{-1}) was comparable with that of Howard (153 g kg^{-1}), Steele-ND (153 g kg^{-1}), and Reeder (155 g kg^{-1}) but was lower ($P < 0.05$) than that of Glenn (157 g kg^{-1}), Dapps (165 g kg^{-1}), Alsen (157 g kg^{-1}), and Parshall (156 g kg^{-1}) (Table 1). In the URN trials, the grain protein of ND 803 was 144 g kg^{-1} compared with 144, 141, 144, 151, and 143 g kg^{-1} recorded for Verde, 2375, Keene, Chris, and Marquis, respectively (Table 2). Other quality data generated from the HRSW-VT grown in North Dakota from 2003 to 2006 (Table 4) show that the falling number of ND 803 (426 s) was not significantly different from those of the most commonly grown HRSW cultivars, including Howard (427 s), Steele-ND (425 s), Alsen (412 s), Parshall (415 s), and Reeder (431 s), except for Glenn (401 s) (Table 4). Flour extraction of ND 803 (695 g kg^{-1}) was comparable with that of most checks, and the mixing time of ND 803 (7.0 min) was significantly shorter than for all checks except for Reeder, which had the same time. The mixing tolerance score (11.8 min) was shorter than that of all checks except for Reeder (12 min). The loaf volume of ND 803 (1013 mL) was comparable with that of most checks except for Parshall (1081 mL) and Glenn (1102 mL). The water absorption of ND 803 (66%) was not significantly different than that of the checks except for Reeder (63.8%; Table 4).

ND 803 should be of interest to many wheat breeders in the USA and worldwide where leaf spotting diseases, such as tan spot, and foliar diseases, including stem and leaf rusts, and FHB are major disease problems. ND 803 is a unique HRSW experimental line that combines resistance to leaf spotting diseases, a very good level of FHB resistance, good bread-making attributes, and high yield. Its relatively low grain-protein content, mixing time, and tolerance compared with current HRSW cultivars were the major reasons it was not released as a cultivar.

Availability

The HRSW breeding program at NDSU will maintain the seed of ND 803. Seed of ND 803 has been deposited in the National Plant Germplasm system, where it will become available for distribution by the NPGS 5 yr after the date of publication. Upon request to the corresponding author,

a small quantity of seed of ND 803 can be obtained for at least 5 yr from the date of this publication for research purposes. Seed distribution for research purposes will be according to the provisions of the Wheat Worker's Code of Ethics (Annual Wheat Newsletter, 1995). Appropriate recognition of the source should be noted if ND 803 contributes to research on agronomic and quality traits, leaf spots, rusts, and FHB or to the development of new genetic stocks, molecular tools, germplasm, or cultivars.

Acknowledgments

The authors thank all the technical staff of the spring wheat breeding program and the wheat quality lab at the Dep. of Plant Sciences, NDSU, Fargo, ND for their contributions in generating agronomic and quality data. Also deep gratitude goes to the colleagues at the NDSU REC for their help in conducting trials and nurseries to evaluate ND 803 and other wheat germplasm.

References

Annual Wheat Newsletter. 1995. Wheat worker's code of ethics. http://wheat.pw.usda.gov/ggpages/awn/41/awn41a2.html#report3 (accessed 15 Oct. 2012).

Busch, R.H., D.V. McVey, G.L. Linkert, J.V. Wiersma, D.O. Warner, R.D. Wilcoxson, G.A. Hareland, I. Edwards, and H. Schmidt. 1996. Registration of 'Verde' wheat. Crop Sci. 36:1418. doi: 10.2135/cropsci1996.0011183X003600050072x

Clark, J.A., H.H. Love, and E.F. Gaines. 1926. Registration of standard wheat varieties. Agron. J. 18:920–922. doi:10.2134/agronj1926.00021962001800100008x

Frohberg, R.C., R.W. Stack, and M. Mergoum. 2004. Registration of spring wheat germplasm ND 2710 resistant to Fusarium head blight. Crop Sci. 44:1498–1499. doi:10.2135/cropsci2004.1498a

Frohberg, R.C., R.W. Stack, and M. Mergoum. 2006. Registration of 'Alsen' wheat. Crop Sci. 46:2311–2312. doi:10.2135/cropsci2005.12.0501

Heiner, R.E., and D.R. Johnston. 1967. Registration of Chris wheat. Crop. Sci. 7:170. doi: 10.2135/cropsci1967.0011183X000700020039x

Lamari, L., and C.C. Bernier. 1989. Evaluation of wheat lines and cultivars to tan spot (*Pyrenophora tritici-repentis*) based on lesion type. Can. J. Plant Pathol. 11:49–56. doi:10.1080/07060668909501146

Lamari, L., S.E. Strelkov, A. Yahyaoui, J. Orabi, and R.B. Smith. 2003. The identification of two new races of *Pyrenophora tritici-repentis* from the host centre of diversity confirms a one-to-one relationship in tan spot of wheat. Phytopathology 93:391–396. doi:10.1094/PHYTO.2003.93.4.391

Mergoum, M., R.C. Frohberg, J.D. Miller, T. Olson, and J.B. Rasmussen. 2005a. Registration of 'Dapps' wheat. Crop Sci. 45:420–421. doi:10.2135/cropsci2005.0420

Mergoum, M., R.C. Frohberg, J.D. Miller, and R.W. Stack. 2005b. Registration of 'Steele-ND' wheat. Crop Sci. 45:1163–1164. doi:10.2135/cropsci2004.308CV

Mergoum, M., R.C. Frohberg, T. Olson, T.L. Friesen, J.B. Rasmussen, and R.W. Stack. 2006a. Registration of 'Glenn' wheat. Crop Sci. 46:473–474. doi:10.2135/cropsci2005.0287

Mergoum, M., R.C. Frohberg, T. Olson, T.L. Friesen, J.B. Rasmussen, and R.W. Stack. 2006b. Registration of 'Howard' wheat. Crop Sci. 46:2702–2703. doi:10.2135/cropsci2006.03.0185

Rudd, J.C., R.D. Horsley, A.L. McKendry, and E.M. Elias. 2001. Host plant resistance genes for Fusarium head blight: I. Sources, mechanisms, and utility in conventional breeding systems. Crop Sci. 41:620–627. doi:10.2135/cropsci2001.413620x

Stack, R.W., R.C. Frohberg, and H.H. Casper. 1997. Reaction of spring wheats incorporating Sumai 3 derived resistance to inoculation with seven Fusarium species. Cereal Res. Comm. 25:667–671.

Stack, R.W., and R.C. Frohberg. 2000. Inheritance of resistance to Fusarium head blight in spring wheat F-1 hybrids. In: Proceedings of the International Symposium on Wheat Improvement for Scab, Nanjing, China. 5–10 May 2000. p. 94–97.